View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by UMP Institutional Repository

LOADING ON ALUMINIUM RIVET JOINT

MUHAMMAD FIKRI BIN MD NAZIAR

Report submitted in fulfillment of requirements for award of the Degree of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

ABSTRACT

Joint is combining two or more component for an application. Rivet joint is a method to joint two components in real world. Nowadays, rivet joint commonly used in manufacturing industry, automobile industry and also in aerospace industry due to the good clam-up, lightweight and good in corrosion resistance. This thesis deal with the loading for a group of aluminium AA5052 blind rivet pop with the steel plate AISI1006. This assessment have two objectives which first to investigate the shear stress on a group of aluminium rivet and second to determine whether centroid of joint influence the strength of joint. Six different geometry of riveted joint was design to achieve the objectives. Three from six design were used to design in variable rivet distance from centroid but constant in angle from centroid meanwhile the other three were designs with constant rivet distance from centroid and different in angle from centroid. The experiment was used the Shimadzu Tensile Test Machine for testing the design in axial force. Result obtained from experiment will be compared to the simulation by using Algor Fempro. From the result, the farthest distance rivets from centroid hold the highest load and the centroid influence the strength of joint. The best position will hold the highest load, highest stress and highest shear is at position of rivet 21mm distance from centroid and angle 51°.

ABSTRAK

Penyambungan adalah persambungan antara dua atau lebih komponen dalam satu aplikasi. Penyambungan menggunakan rivet adalah salah satu cara yang digunakan dalam bidang kejuruteraan. Masa kini, teknik penyambungan rivet telah banyak digunakan dalam bidang industri pembuatan, industri permotoran dan industri perkapalan. Laporan ini mengisahkan daya tahan sekumpulan aluminium rivet pop jenis AA5052 dengan plat besi. Laporan ini mempunyai dua objektif. Objektif yang pertama adalah untuk mengkaji kekuatan rivet pada penyambungan plat besi melalui ujian tegangan dan yang kedua adalah untuk mengkaji samada titik tengah penyambungan plat besi mempengaruhi kekuatan penyambungan rivet. Enam berlainan kedudukan rivet digunakan untuk mengkaji dan mencapai objektif. Tiga daripada enam rekabentuk direka dengan berlainan jarak rivet daripada titik tengah penyambungan tetapi sudut antara rivet dan titik tengah penyambungan ditetapkan manakala lebihan tiga rekabentuk direka dengan berlainan sudut dari titik tengah penyambungan tetapi jarak antara rivet dari titik tengah penyambungan ditetapkan. Keputusan eksperimen akan dibandingkan dengan keputusan simulasi menggunakan Algor Fempro. Daripada hasil keputusan, jarak rivet yang jauh dari titik tengah akan menanggung berat yang paling tinggi, tekanan yang tinggi dan daya ricih yang tinggi pada kedudukan rivet dari titik tengah penyambungan ialah 21mm dan bersudut 51° dari titik tengah penyambungan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

σ	Standard Deviation
N	Number of specimen
x_i	Observe value of specimen
$\bar{x}$	Mean Value

LIST OF ABBREVIATIONS

DLJ	Double Lap Joint
DIC	Digital Image Correlation
FEA	Finite Element Analysis
FEM	Finite Element Method
PEO	Percentage of Error
AA	Aluminum Alloy
Al	Aluminium

CHAPTER 1

INTRODUCTION AND GENERAL INFORMATION

1.1 PROJECT BACKGROUND

Rivets are considered to be permanent fasteners. Riveted joints are therefore similar to welded and adhesive joints. When considering the strength of riveted joints similar calculations are used as for bolted joints. Rivets have been used in many large scales applications including shipbuilding, boilers, pressure vessels, bridges and buildings. In recent years there has been a progressive move from riveted joints to welded, bonded and even bolted joints A riveted joint, in larger quantities is sometimes cheaper than the other options but it requires higher skill levels and more access to both sides of the joint. Rivets for mechanical and structural applications are normally made from ductile (low carbon) steel or wrought iron. For applications where weight, corrosion, or material constraints apply, rivets can be made from copper aluminum.

Nowadays, there are a lot of application is applying rivet joint to assemble. Rivet is used for joining two members of any structure and is used for developing the permanent joint which is by method something between bolting and welding. In fact rivets are bolt like items with heads but without threads which are inserted in the holes made in members from one end for jointing and since there are no threads on the body of rivets for mounting the nuts and tightening the members those ends are instead flattened by hammering manually or by electrical/pneumatic hammers to develop the grips so that the members are joined. These rivet joint is very good solution to resist any load like tensile load but without good design of joint, it can give trouble or in other words is dangerous for users. Without good design of joint, it can easily got failure from rivet even though only for small load. If properly design with a good experiment, rivet joint can hold a larger load for the structure.

In a rivet joint with tensile loading, the rivets are sharing the load in shear, bearing in the rivet, bearing in the member, and shear in the rivet. When one rivet is failed, another rivet will begins to carry the load until all the rivets will fail. The right position of rivet need to correctly design to make all rivets is shared same load when they are subjected with load. Two rivets with close distance shared higher load than one rivet alone or far from another rivets.

In this project, it needs to investigate the shear joint failure owing to tensile loading for a group of aluminum rivets. In designing of semi-permanent joints of two plates under tensile loading, the position of the rivets will be essential to ensure load is well distributed on the joints (rivets). Most of the available methods have been developed to estimate the loading capacity using side-edge distance but not the best position of pin group under tensile loads based on the assumptions of angle and distance from centroid. The investigation use aluminum rivets as connector to joint two plates made of steel. It will be tested with rivets located at various positions and tested until at least one pin failed. The primary investigations have to be simulated using ALGOR for the optimum positions. The analysis is used to find the lowest stress from four pins and first pin that failed. In this experiment, the expected result to be is the closer distance of aluminum rivet to the centroid axis the higher load the rivet can support.

1.2 PROBLEM STATEMENT

Basically, there is less research about fastener joints that focusing on centroid of joining plate. It more research on the layout of fastener, diameter and material of fastener. In this experiment, it needs to investigate the shear joint failure for a group of aluminum rivet. For that, it needs to be design the best position of aluminum rivets joint for steel plate. From the design, it can be supported any load subjected and from that analyze on shear joint failure on the aluminum rivets. From this, it can be consume that if designing a rivet joint is worse, it can be dangerous for any life of using the joint such as in aircraft industry or construction. Take aircraft as example, if the rivet joint are not in good position to carry the load, it can give risk to passengers while flying even dangerous while taking off. From this case, the right position with a best designing for aluminum rivets are very important to support highest load and overcome the failure.

1.3 PROJECT OBJECTIVES

i. To investigate the shear joint failure to tensile loading for a group of aluminums rivet.
ii. To investigate whether centroid of joint influence the strength of aluminum rivets joint.

1.4 PROJECT SCOPE

i. The tensile load and size of specimen will be governed by the mounting on the Universal Testing Machine (Shimadzu Autograph AG-X Series, Max load 100kN).
ii. Aluminum rivets (AA5052) are use on steel base plate (AISI1006).
iii. Variation will be distance between rivets, 7mm, 14mm, 21mm and angles 30^{o}, 45^{o}, 50^{o} using centroid as reference.
iv. Standard rivet size is used= Rivet size diameter 3mm and length is nominal length 9.5mm

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Determine the shear stress for aluminum rivet is one of experiment objective. A research about these element have done and it primarily covered deformation of rivets, load distribution failure and damage tolerances design of rivet joint, tensile strength, shear strength and effective stress for rivet and steel plate. From this research, a few rivet has been use for investigating its structure and behavior in term of strength and structure. Besides that, one research for modeling of steel adhesive joints reinforced by rivets have been done by T. Sadowski, M. Knec and P. Golewski from Lublin University of Technology at Poland on March 2010. From this, it can be explain on how the rivet deformation and also stress concentration in different parts of the joint. A few factor need to take noted for design layout for rivet joint. It needs to be focus in terms of distance of rivet with the end and edge, the spacing between rivet, ultimate load of rivet and also its strength. Extensive research has been done in the past to study the fastener lap joint such as rivet, pin and bolt joints. Literature review present with preview of the past studies on fastener joint. Various experimental and finite element analysis conducted on the fastener joints are available in this review.

2.2 BACKGROUND OF STUDY

(Miqual Casafont, January 2006) has developed an experimental testing of joint for seismic design of lightweight structures of screw joints in straps. For this paper, it is deal with seismic response of lightweight steel structure. It will discuss about design guide for engineers including method analysis and rule about detailing that are contribute in industry nowadays. This guidance must take into account that mass and stiffness are quite different from conventional steel structure. For any type of structure, two basic seismic requirements are enough lateral stiffness to resist seismic loads without significant structural damage and energy dissipation mechanisms is through plastic deformation. Fasteners working as shear connections are the most effective mechanism of force transfer due to their good behavior in terms of stiffness, strength and deformation capacity. There have several different types of fasteners can be used such as rivets, bolts, screw and pins. The objective of this experiment is to obtain parameters such as the initial stiffness, yield load, ultimate load and maximum displacement. Second objective is to complete force-displacement curve, needed for the finite element modeling of x-braced frames and lastly is to identify the various failure modes. For this experiment, it will be analyze result in order to classify the various failure modes in terms of their seismic strength and ductility.

Figure 2.1: Screw joint

Source: Miqual Casafont (2006)

In this experiment, it uses two different diameters were used to connect the straps: 4.8 and 6.3mm. The shaft length of the 4.8 mm diameter screws was always 10 mm for threaded part and they could have either flat and square heads or hexagonal heads. The shaft of the 6.3 diameter screws, whose head was always hexagonal, could be 10 or 30 mm long for threaded part. The length of the steel straps ranged between 350 and 475 mm, depending on the number of screws of the joint. Their thickness was also variable from 0.85 to 3 mm, but their width was always the same, 100 mm. For the layout design for this experiment as be shown by the picture below. The picture shows the position of the screws: the spacing and the longitudinal and transverse edge distances. The joint layout was identical for all the specimens.

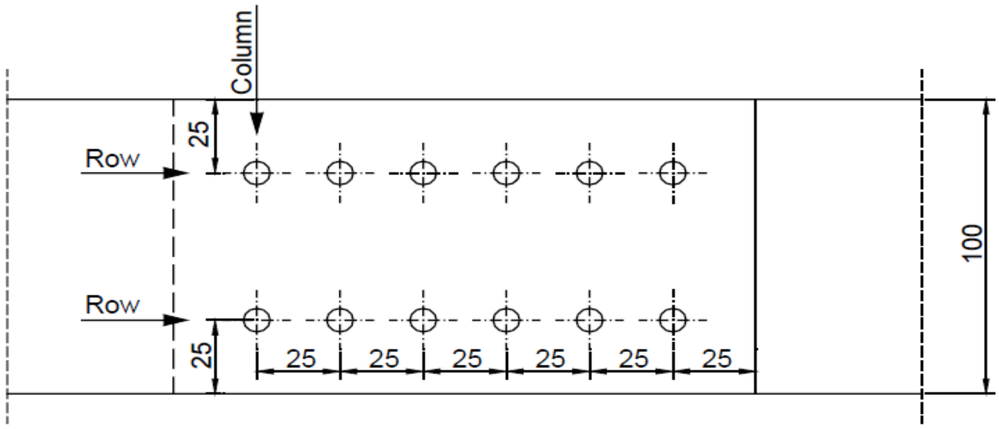

Figure 2.2: Layout of screw

Source: Miqual Casafont (2006)

This experiment investigation performed on the behavior of screwed connections has allowed distinguishing two types of joints depending on the mode of failure. For the first result there are those joints that fail in a combination of tilting, bearing and pull out or sometimes it goes for pull through. For the second result there is a second group of joints whose failure mode is basically a combination of tilting and net section failure. By analyzing the result, the distinction between these groups is very important. It is because the joint have enough strength to allow the cyclic yielding of the diagonals. There can be dissipative action, which takes place in the load interval between the yielding load of the strap gross cross-section and the ultimate load of joint. the displacements corresponding to experimental strengths range from about 5 to 7 mm, depending on the number of screw columns. The collapse of the joint takes place later than expected and also for higher loads.

(Hitoshi Kuwamura, March 2007) has using finite element method to modeling of bolted connection in thin wall stainless steel plate under static shear. In this study, based on the existing test data for calibration and parametric study, finite element (FE) model with three-dimensional solid elements using ABAQUS program is established to investigate the structural behavior of bolted shear connections with thin-walled stainless steel plate. Non-linear material and non-geometric analysis is carried out in order to predict the load–displacement curves of bolted connections. Experimental research regarding two types of bolted connections: single shear and double shear connections, fabricated from thin-walled stainless steel using 1.5 or 3.0mm thick plate and 12 mm/15mm diameter bolt were carried out by Kuwamura. **Figure 2.3** and **2.4** display geometry of test specimens and test set-up of specimen (series SA). The both ends of test specimens were gripped through chucks onto a tensile test machine that is Universal Testing Machine by which a tensile force was applied gradually to the test specimen in monotonic displacement control.

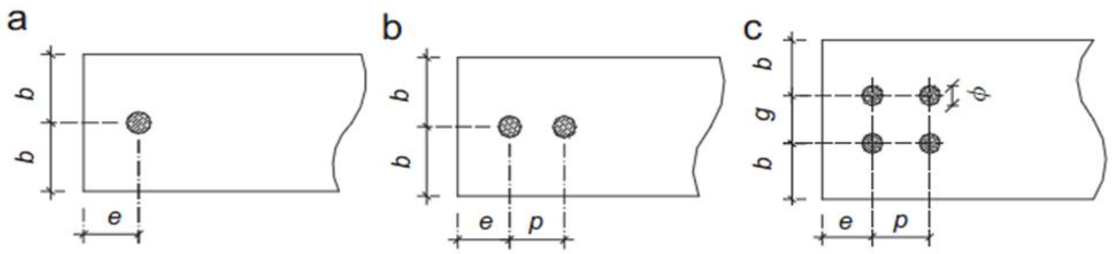

Figure 2.3: Geometry of test specimen

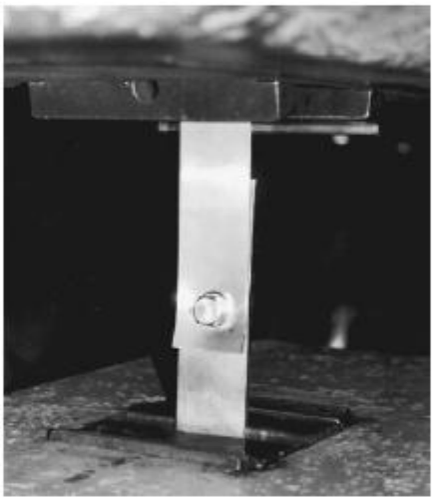

Figure 2.4: Test set up for specimen

Source: Hitoshi Kuwamura, (2007)

The objective of Finite Element Method analysis is not to describe reality as accurately as possible, but to find the simplest model resulting in a sufficiently accurate description of reality. For the experimental results, the purpose of this research is to predict the ultimate behaviors such as failure mode, ultimate strength and the occurrence of curling for thin-walled stainless steel bolted connections through the FE analysis. Test results of eight specimens with two kinds of plate thickness and three types of bolt arrangements were used to calibrate the FE models. The FE model predicted accurately the curling of bolted connections, which was occurred in the experimental results and could also trace the entire load–displacement path. In addition, with the Finite Element analysis results, the yield patterns, deformed shapes and stress/strain distributions in bolted connections were possible to be scrutinized in detail at specified displacement level. A variety of parametric studies were performed in order to investigate the influence of the curling (out of plane deformation) on the ultimate strength of bolted connections. From this experiment, Kuwara has noted that if curling is occurred in the Finite Element model after the ultimate strength is reached, the curling has negligible influence on the ultimate strength of bolted connections.

(Billy Kelly, 2004) is using FEA modeling of setting and mechanical testing of blind rivets. His paper describes simulation of the setting of a blind rivet, using an axisymmetric model in the MSC.MARC/Mentat FEA package. Mechanical fastener joints, including blind rivets, are widely used in industry including the aerospace industries. In general there are two types of failure observed in mechanical fasteners: shear failure and tensile failure. Other failure modes such as tension, shear-out, bearing, cleavage and pull-out may be observed in the structures being joined. The finite element technology has grown from an academic arena into the industrial world and has dramatically changed the way in which components are designed and made. Due to the complexity of the material and geometry non-linearity involved, metal forming has attracted great attention from researchers. The ability to accurately model mechanical fasteners is fundamental to understanding the failure mechanisms involved. Modeling of the failure mechanisms of fasteners in shear and tensile failure may be modeled using 3D finite element modeling. To simplify the rivet model detail and reduce processing time, 2D-axisymmetric modeling of the setting process and tensile failure mode may be used. The blind rivet components, mandrel and rivet; can be seen in **Figure 2.5**.

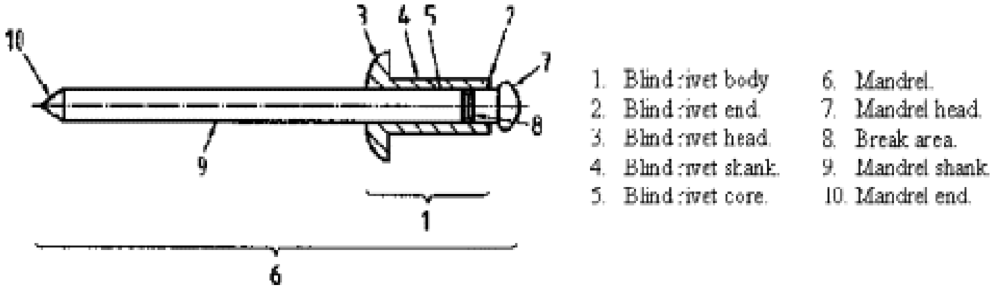

Figure 2.5: Blind rivet elements. BS EN ISO 14555:2001 (blind rivets—terminology and definitions.

Source: Billy Kelly (2004)

The model must accurately deal with contact friction, separation issues, and computational expense of the model and accurate geometrical definition of the components. The analysis of forming force on the head of the mandrel from both mechanical testing and modeling can be compared. The formed shape of the set rivet can be compared to that predicted by the FE analysis. The final stage of the analysis deals with the forces involved, in physical and simulated tensile failure. The mechanical testing of the blind rivets was pre-formed in two ways. The first is the analysis of setting forces in the rivet and secondly is the tensile testing of the set rivet. The more symmetric the rivet body remains during forming, the lower the initial forming forces are. For non-symmetric rivets the force increases more rapidly over the distance travelled, and the mandrel breaks at an earlier position to that of the symmetric shaped rivets. In this experiment, Billy has made up a conclusion that is simulation of the setting of a blind rivet accurately predicts actual deformed shape and the location of failure in the rivet under a tensile load can also be seen. Secondly is the FE model developed accurately predicts the forces involved in the forming of the rivet in comparison to the physical results and the model however does not accurately predict the failure of the rivet in tension. Last conclusion is the axisymmetric FE models cannot predict non-symmetric behavior in the setting of blind rivets. The development of full 3D-models is required for this. The degree of instability within the forming of the rivet can be seen to directly affect setting force.

(MD Aniello, November 2010) has develop experiment to investigate on shear behavior of riveted connection in steel structure. In this paper, the experimental investigation allowed the influence of various parameters on the response of the connections to be assessed, such as load eccentricity, variation in net area, plate width and number of rivets. The experimental results and predicted shear strengths were compared in order to evaluate the reliability of the provisions of EN 1993:1-8. On the basis of the results obtained, modifications are proposed to the design equations given by EN 1993:1-8 for the rivet shear strength and the ultimate resistance of the net cross-section. The technique used to perforate the plates may also affect the connection strength and fatigue life of riveted structures. In old metal structures, holes were obtained by techniques such as: drilling, punching, sub-drilling and reaming, punching and reaming. Their effects on shear connections are important when splices fail in tension on the net section. Indeed, early tests showed that splices made of plates with drilled holes exhibited a large deformation with high necking, while in the case of punched holes the failure occurred in a brittle manner without evident necking. To analyze the influence of different parameters on the shear capacity of typical lap shear connections representative of historic structural typologies as example of roofing structures, low-rise buildings and bridges in terms of structural verification according to the modern codes, a wide experimental investigation was carried out within the framework.

From the result, Aniello was highlighted that the shear behavior is strictly dependant on the geometry of the joint and the loading conditions. In the case of unsymmetrical specimens the load eccentricity induced a secondary bending moment, showing significant out-of-plane displacements, which tend to lift off one plate from the adjacent one at each connection. Tests showed that the effects of bending are mainly confined to the regions where plate discontinuities occur. As the joint length increases so bending will become less pronounced and the influence on the behavior of the connection should decrease. In other hand, all specimens which failed in tension on the net section exhibited ultimate tensile strengths of perforated plates higher than those found in the unaxial coupon tests. This effect has also been found by other researchers and it is known as the ‘‘net efficiency’’. This phenomenon may be attributed to the fact that the presence of the hole also gives rise to transverse stresses generating a sort of multiple-stress effect, emphasized by the presence of clamping force in the rivets, which avoid free lateral contractions in their vicinity. For result of plate width, it is show that plate width is another parameter which influences the net efficiency.

This can be proved by observing for specimen, which failed in tension in the net area, where two different plate widths were investigated for the same geometric parameters. By this observation, indeed, increasing the plate width increased the ultimate strength of the connection. For the result of effect of joint length, tests showed that joint length is an important parameter that influences the ultimate strength of the joint, especially for single lap shear connections. Although the present study did not explicitly aim to investigate the influence of pitch on shear capacity and specific parametric tests were not performed, tests showed that the examined range of spacing did not appreciably influence the shear strength. From all the result, Aniello has made of conclusion. The experimental results highlighted that a considerable amount of out-of-plane deformation occurred in unsymmetrical joints. It is clear that the effects of bending were mainly confined to the regions where plate discontinuities occurred. Obviously, as the joint length increased, bending was less pronounced, and its influence on the behavior of the connection decreased.

The influence of bending was most pronounced in the splice with only a single fastener in the direction of the applied load. In such a joint the fastener was not only subjected to single shear, but a secondary tensile component may also be present. Furthermore, the plate’s material in the direct vicinity of the splice was subjected to high bending stresses due to the eccentricity of the load. Hence, the bending tended to slightly decrease the ultimate strength of short connections. The shear strength of longer unsymmetrical joints seemed to be less affected by the effects of bending. The experimental over-strength in the bearing failure mode may be due to the contribution